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Technical Report II - 8

The Effect of Reynolds Number on the Diffraction of a Shock Wave

by

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Technical Report II - 8

The Effect of Reynolds Number on
the Diffraction of a Shock Wave

On the general subject of diffraction of shock waves over obstacles, the shock strength, Reynolds number, time and shape of obstacle are some of the important parameters. This report throws some light on the effect of Reynolds number and time on the pressure distribution as a shock front turns a 90° corner. This research is in partial fulfillment of a contract between Princeton University and the Office of Naval Research, the latter furnishing the major financial support.

Submitted by

February, 1951 Walker Bleakney

THE EFFECT OF REYNOLDS NUMBER ON THE DIFFRACTION OF A SHOCK WAVE

When experiments are made on models of reduced size the question concerning the extrapolation of the results to a different scale always arises. This is a familiar problem in the use of wind tunnels in the field of aerodynamics, but experience here cannot be applied with confidence to the diffraction of a shock wave around a body because of the very transient nature of this problem. Extensive studies of diffraction patterns (1, 2, 3) have not included any large variation of the Reynolds number. In view of the importance of relating these results to shock wave pressures on large structures it was decided to extend the experiments on the simple step-down corner to include as large a variation in Reynolds number as possible.

The experiments were carried out in the shock tube previously described (4). Two models were used of the shape sketched in Fig. 1. One was of length D = 2 inches and the other D = 14 inches. The experiments were carried out using a shock pressure ratio $\xi = p_o/p_1 = 0.61$ across the incident shock front and two values of p_o, 50 and 475 mm Hg. The dimension D was used as the characteristic length in computing the Reynolds number. Between the smaller model at the lower pressure and the larger one at the higher pressure a change in Reynolds number from 1.5×10^5 to 1×10^7 or a factor of 67 was obtained. With each model observations were made at both pressures and at from 5 to 10 different times ranging from 50 to 500 microseconds. The table summarizes the variation in parameters.

ξ	D	P_o	t
0.61	2 in.	50 mm	50 μs
	14 in.	475	:
			500

A typical interferogram is shown in Fig. 2. No appreciable disturbance of the flow field near the corner was detectable from the leading edge of the horizontal surface. Altogether about 25 such pictures were taken and the density contours plotted from the fringe shifts using methods described in Ref. (1, 3). The pressures on the walls were calculated from these densities

and curves of pressure on the surface versus distance from the corner were plotted. Representing the pressure and distance by dimensionless variables p/p_o and x/L defined as in Fig. 1 the pressures for different times could all be plotted in the same coordinates. Indeed within the accuracy of the experiments the pressures for different times all fell on the same curve. The accuracy was least, $\pm$ 8%, at the lower pressure and smaller model, especially near the eddy at the corner, while for the larger model and higher pressure the scatter was reduced to less than 2%. Deviations of points from the mean curve bore no correlation with the time at which the picture was taken and it was therefore concluded in this first phase that the pressure pattern on the walls grew radially from the corner always remaining similar to itself until disturbances entered the field from a distance. In fact it was observed, although no careful measurements were made concerning this point, that the pictures themselves as well as the whole density field obeyed this rule.

Having shown that pressure patterns at different times could be reduced to the same form it remained to compare the effects at different Reynolds numbers. This is done in Fig. 3 where each point is an average for a given x/L of the values taken from all the curves representing different times for this particular model and p_o. The upper branch of each curve represents the pressure along the horizontal surface and the lower branch that along the vertical wall. There seems to be no marked correlation here with Reynolds number the deviations being ascribable to uncontrolled experimental variations.

Within the range of variables studied, then, the conclusion is reached that no appreciable scale effect exists for the diffraction of a shock wave around a 90° corner. This result may not be surprising since the separation of the flow from the surface undoubtedly takes place at the same point in all cases, namely the corner itself. If the diffraction were to take place around a smooth surface the conclusions reached here may be invalidated.

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FIGURES

1. Schematic illustration of obstacle, shock wave and notation.

2. Typical interferogram of shock turning a 90° corner.

3. Pressure distribution on the two walls forming the corner. Upper branch gives pressure on horizontal surface; lower branch on the vertical.

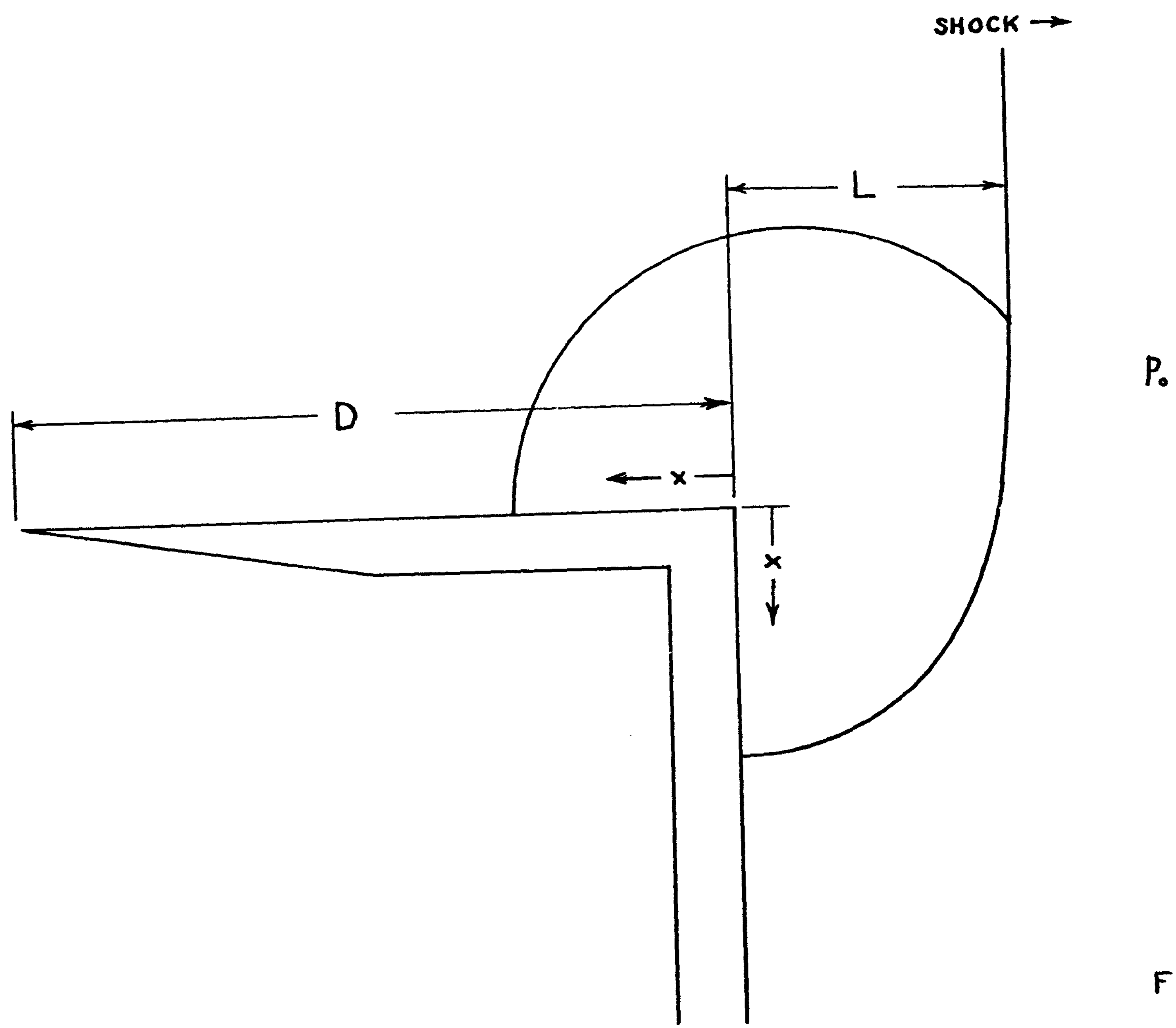

FIG. 1

FIG 2

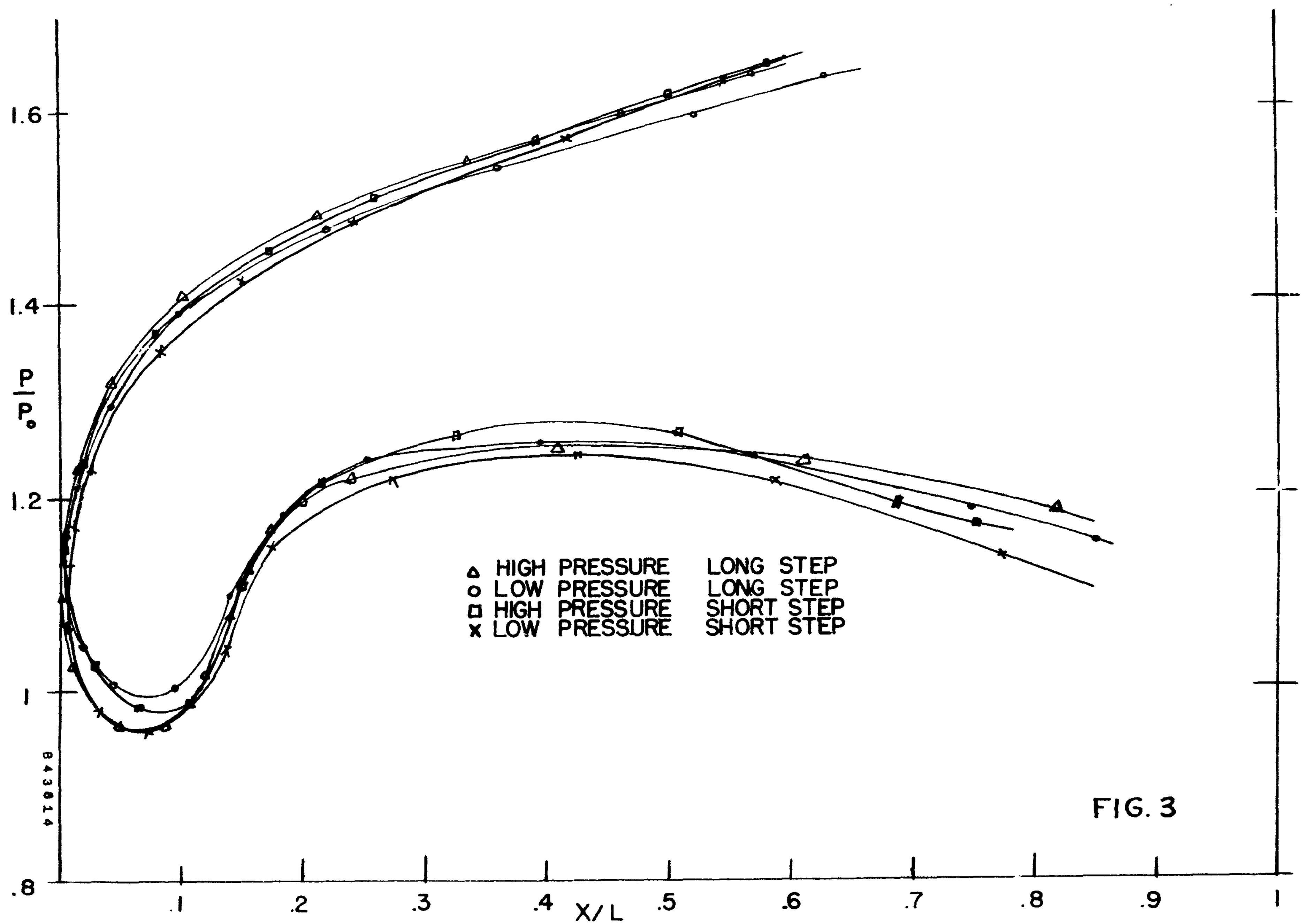
1.6
1.4
P/Po
1.2
1
.8
.1
.2
.3
.4
.5
.6
.7
.8
.9
1
X/L
HIGH PRESSURE LONG STEP
LOW PRESSURE LONG STEP
HIGH PRESSURE SHORT STEP
LOW PRESSURE SHORT STEP
843814

FIG. 3